CLAIMS

1. Droplet deposition apparatus comprising chamber walls defining a liquid chamber, one of said chamber walls being resiliently deformable in an actuation direction; an ejection nozzle connected with the chamber; a liquid supply providing for continuous flow of liquid through the chamber; acoustic boundaries serving to reflect acoustic waves in the liquid of the chamber; and an actuator remote from the chamber and the liquid supply, acting in said actuation direction upon said resiliently deformable chamber wall to create acoustic waves in the liquid of the chamber and thereby cause droplet ejection through said nozzle.

2. Apparatus according to Claim 1, wherein said acoustic boundaries serve to negatively reflect acoustic waves in the liquid of the channel.

3. Fluid pumping apparatus comprising chamber walls defining a fluid chamber, one of said chamber walls being resiliently deformable in an actuation direction; a chamber outlet, and an actuator remote from the chamber, acting in said actuation direction upon said resiliently deformable channel wall to create acoustic waves in the chamber and thereby cause fluid flow in the chamber outlet.

4. Apparatus according to any one of Claims 1 to 3, wherein said resiliently deformable chamber wall forms a seal isolating the actuator from fluid in the chamber.

5. Apparatus according to any preceding claim, wherein said fluid chamber comprises an elongate liquid channel, and wherein said resiliently deformable chamber wall comprises an elongate channel wall.

6. Apparatus according to any one of the preceding claims, wherein said resiliently deformable chamber wall comprises a substantially rigid element capable of transmitting force from the actuator to fluid in the channel and at least one first flexure element.

7. Apparatus according to Claim 6 when dependent on Claim 5, wherein said at least one flexure element extends substantially across the full width of the resiliently deformable channel wall.

8. Apparatus according to Claim 6 when dependent on Claim 5, wherein said at least one flexure element extends across a portion of the width of the resiliently deformable channel wall.

9. Apparatus according to any one of Claims 6 to 8 when dependent on Claim 5, wherein said rigid element extends along the length of the channel.

10. Apparatus according to any one of Claims 5 to 9, wherein said resiliently deformable chamber wall comprises a plurality of flexure elements arranged to constrain movement of the rigid element to said actuation direction.

11. Apparatus according to Claim 10, wherein at least one of said flexure elements contacts fluid in the channel and is stiff with respect to fluid pressure.

12. Apparatus according to any one of Claims 5 to 11, wherein said flexure elements are arranged in a parallelogram linkage with respect to the rigid element.

13. Apparatus according to any one of Claims 5 to 12, wherein the actuator comprises a push-rod acting on said rigid element.

14. Apparatus according to Claim 13, wherein the push-rod is carried on said rigid element.

15. Apparatus according to Claim 13 or Claim14, wherein the push-rod serves as the armature in an electromagnetic actuator arrangement.

16. Apparatus according to any one of Claims 13 to 15, further comprising support means connected to the push rod at a location spaced apart from said

rigid element in the actuation direction, wherein said support means constrains movement of said push rod to the direction of actuation.

17. Apparatus according to Claim 16, wherein said support means comprises one or more second flexure elements connected to said push rod at a location spaced apart from said rigid element, said first and second flexure elements arranged to act like a parallelogram linkage with respect to the push rod.

18. Apparatus according to any one of the preceding claims, wherein the actuator operates electromagnetically.

19. Apparatus according to any one of Claims 15 to 18, wherein the actuator comprises an armature displaced through modulation in flux distribution.

20. Apparatus according to any one of the preceding claims, comprising a first planar component comprising a plurality of rigid channel walls corresponding with a set of channels; and a plurality of nozzles aligned with said channels; and a second planar component disposed parallel with the first planar component, the second planar component comprising a plurality of actuators aligned with said channels.

21. Apparatus according to Claim 20, wherein said set of channels are elongate and arranged parallel to one another.

22. Apparatus according to Claim 20 or Claim 21, wherein the first planar component further comprises a resiliently deformable channel wall for each channel.

23.Apparatus according to Claim 20 or Claim 21, wherein the second planar component further comprises a resiliently deformable channel wall for each channel.

24. Apparatus according to any one of Claims 20 to 23, wherein said first component is integral.

25. Apparatus according to any one of Claims 20 to Claim 24, wherein said first component is manufactured by a process comprising the step of etching away material to define the channel walls.

26. Apparatus according to any one of Claims 20 to Claim 24, wherein the channel walls are formed by machining.

27. Apparatus according to any one of Claims 20 to Claim 24, wherein the channel walls are formed by electroforming.

28.Apparatus according to any one of Claims 20 to Claim 27, wherein said first component is formed from silicon.

29. Apparatus according to any one of Claims 20 to Claim 28, wherein said second component is a laminate manufactured through the repeated formation and selective removal of layers.

30. Apparatus according to Claim 29, wherein each layer may comprise more than one material.

31. Apparatus according to any one of the preceding claims wherein at least one distinct region is defined in the resiliently deformable channel wall, with the or each region being movable in translation in the actuation direction through resilient deformation of the wall, the or each said region being stiff.

32. Apparatus according to Claim 31, wherein there exist two or more said regions.

33. Apparatus according to Claim 32, wherein one or more of said regions can be actuated independently of another region.

34. Apparatus according to Claim 32 or Claim 33, wherein the actuator acts upon more than one region.

35. Apparatus according to Claim 32 or Claim 33, comprising a plurality of like actuators associated respectively with said regions.

36. A generally planar component for use in fluid pumping apparatus comprising:

a first planar layer having resiliently deformable portions;

a second planar layer parallel to said first layer having corresponding resiliently deformable portions; and

a plurality of actuators having an actuation direction, located between said two layers and connected to interior surfaces of said two layers with the direction of actuation orthogonal to the two layers;

wherein said actuators are operable to deform selected resiliently deformable portions of said first and second layers in an actuation direction so as to cause a change in pressure of a liquid in contact with the exterior of said first planar layer.

37. A generally planar component according to Claim 36, wherein said first planar layer is impermeable.

38. A generally planar component according to Claim 36 or Claim 37, wherein said second planar layer is permeable.

39. A generally planar component according to any one of Claims 36 to 38, wherein said actuators comprise rigid push rods connected between corresponding resiliently deformable portions of said first and second planar layers.

40. A generally planar component according to Claim 39, wherein said push rods are constrained by said first and second planar layers to move only in the direction of actuation.

41. A generally planar component according to Claim 39 or 40, wherein said push rods serve as the armature in an electromagnetic actuator arrangement.

42. A generally planar component according to any one of Claim 36 to 41, wherein said resiliently deformable portions of one layer each have a direction of elongation, the directions of elongation being parallel.

43. A method of constructing a fluid pumping apparatus comprising the steps of:

forming a first planar component according to any one of Claims 36 to 42;

forming a second planar component comprising a plurality of rigid channel walls defining open sided channels corresponding to the resiliently deformable portions of said first planar component; and

mating the two planar components such that they are parallel and such that the channels of the second planar component are aligned with the resiliently deformable portions of the first planar component, which thus form part of a resiliently deformable channel wall.

44. A method according to Claim 43, wherein the first planar component comprises one resiliently deformable portion for each channel.

45. A method according to Claim 43, wherein the first planar component comprises more than one resiliently deformable portion for each channel.

46. Fluid pumping apparatus comprising elongate channel walls defining an elongate fluid channel, the channel having a fluid outlet, one of said channel walls having at least one distinct region movable in translation in an actuation direction orthogonal to the length of the channel and at least one straight line actuator acting in said actuation direction upon said region of the channel wall to create an acoustic wave in the channel and thereby expel fluid from said outlet.

47. Apparatus according to Claim 46, wherein said straight line actuator comprises an armature movable bodily under electromagnetic force in a straight line in the actuation direction.

48. Apparatus according to Claim 47, wherein said armature is constrained to movement in said straight line.

49. Apparatus according to Claim 49, wherein said armature is constrained by elements functioning as a parallelogram linkage.

50. Apparatus according to any one of Claims 46 to 49, wherein said region is elongate and extends along a substantial portion of the acoustic length of the channel.

51. Apparatus according to any one of Claims 46 to 50, wherein there are provided at least two said regions.

52. Apparatus according to Claim 51, wherein the actuator acts upon more than one region.

53. Apparatus according to Claim 52, comprising a plurality of like actuators associated respectively with said regions.

54. Apparatus according to any one of Claims 46 to 53, wherein said fluid outlet comprises a droplet deposition nozzle.

55. Apparatus according to any one of Claims 46 to 54, comprising a plurality of like channels each having a respective actuator, the actuators having parallel actuation directions.

56. Apparatus according to any one of Claims 46 to 54, in the form of an ink jet printer.

57. Droplet deposition apparatus comprising a liquid chamber capable of sustaining acoustic waves travelling in the liquid, a droplet ejection nozzle positioned for the ejection of a droplet in response to said acoustic waves and an electromagnetic actuator serving on receipt of an electrical drive signal to create an acoustic wave in the chamber and thereby effect droplet ejection.

58. Droplet deposition apparatus according to Claim 57, wherein the actuator is remote from the chamber.

59. Droplet deposition apparatus according to Claim 57 or 58, wherein the chamber is defined by chamber walls, one of said chamber walls being resiliently deformable in the actuation direction under the action of said actuator.

60. Droplet deposition apparatus according to Claim 59, wherein said resiliently deformable chamber wall forms a liquid seal isolating the actuator from liquid in the chamber.

61. Droplet deposition apparatus according to any one of Claims 57 to 60, further comprising acoustic boundaries serving to reflect acoustic waves in the liquid of the chamber.

62. Droplet deposition apparatus according to any one of Claims 57 to 61, further comprising a liquid supply providing for continuous flow of liquid through the chamber.

63. Droplet deposition apparatus according to any one of Claims 57 to 62, wherein the actuator comprises an armature displaced through modulation in distribution of a magnetic flux of substantially constant magnitude.

64. Droplet deposition apparatus according to any one of Claims 57 to 63, wherein said liquid chamber comprises an elongate liquid channel

65. Droplet deposition apparatus according to Claim 64, wherein the actuator operates in an actuation direction orthogonal to the channel length.

66. Droplet deposition apparatus according to Claim 64 or Claim 65, wherein the actuator extends along substantially the length of the channel.

67. Droplet deposition apparatus according to any one of Claims 64 to 66, comprising acoustic boundaries at respective opposing ends of the channel.

68. Droplet deposition apparatus according to any one of Claims 64 to 67, wherein the ejection nozzle is connected with the channel at a point intermediate its length.

69. Droplet deposition apparatus according to any one of Claims 64 to 68, comprising a first planar component comprising a plurality of rigid chamber walls corresponding with a set of chambers; and a plurality of nozzles aligned with said chambers; and a second planar component disposed parallel with the first planar component, the second planar component comprising a plurality of actuators aligned with said chambers

70. Droplet deposition apparatus according to Claim 69, wherein the first planar component further comprises a resiliently deformable chamber wall for each chamber.

71. Droplet deposition apparatus according to Claim 69, wherein the second planar component further comprises a resiliently deformable chamber wall for each channel.

72. Droplet deposition apparatus according to any one of Claims 69 to 71, wherein said first component is integral.

73. Droplet deposition apparatus according to any one of Claims 69 to Claim 72, wherein said first component is manufactured by a process comprising the step of etching away material to define the chamber walls.

74. Droplet deposition apparatus according to any one of Claims 69 to Claim 72, wherein the chamber walls are formed by machining.

75. Droplet deposition apparatus according to any one of Claims 69 to Claim 72, wherein the chamber walls are formed by electroforming.

76. Droplet deposition apparatus according to any one of Claims 69 to Claim 75, wherein said first component is formed from silicon.

77. Droplet deposition apparatus according to any one of Claims 69 to Claim 76, wherein said second component is a laminate manufactured through the repeated formation and selective removal of layers.

78. Droplet deposition apparatus according to Claim 77, wherein each layer may comprise more than one material.

79. Droplet deposition apparatus comprising an elongate liquid channel bounded in part by a resiliently deformable diaphragm; a liquid supply for the channel; an ejection nozzle communicating with the channel; and a push-rod which is separated from the liquid by the diaphragm, the push-rod being displaceable in an actuation direction orthogonal to the length of the channel to deform the diaphragm to displace liquid in the channel and thereby cause droplet ejection through said nozzle, wherein the push-rod is supported by at least one flexural element at two locations spaced one from the other in the actuation direction.

80. Droplet deposition apparatus according to Claim 79, wherein the push-rod is constrained by said at least one flexural element against rotation about an axis parallel to the length of the channel.

81. Droplet deposition apparatus according to Claim 79 or Claim 80, wherein the push-rod is supported by at least one flexural element at each said location, the flexural elements serving as a parallelogram linkage.

82. Droplet deposition apparatus according to any one of Claims 79 to 81, wherein the diaphragm serves as one said flexural element.

83. Droplet deposition apparatus according to any one of Claims 79 to 82, wherein the push-rod is integral with the diaphragm.

84. Droplet deposition apparatus according to any one of Claims 79 to 83, wherein the nozzle opposes the diaphragm in the actuation direction.

85. Droplet deposition apparatus according to any one of Claims 79 to 84, wherein the diaphragm extends along the length of the channel.

86. Droplet deposition apparatus according to any one of Claims 79 to 85, wherein at least one of said flexure elements contacts liquid in the channel and is stiff with respect to liquid pressure.

87. Droplet deposition apparatus according to any one of Claims 79 to 86, wherein the push-rod communicates at end remote from the diaphragm with an actuator.

88. Droplet deposition apparatus according to Claim 87, wherein the actuator comprises an electromagnet actuator.

89. Droplet deposition apparatus according to any one of Claims 79 to 88, wherein the push-rod serves as the armature in an electromagnetic actuator.

90. Droplet deposition apparatus according to Claim 88 or Claim 89, wherein the actuator comprises an armature displaced through modulation in flux distribution.

91. Droplet deposition apparatus according to any one of Claims 79 to 90, further comprising acoustic boundaries at respective opposing ends of the channel serving to reflect acoustic waves in the liquid of the channel; deformation of the diaphragm by the push-rod serving to create acoustic waves in the liquid of the channel and thereby cause droplet ejection through said nozzle.

92. A method of manufacturing droplet deposition apparatus, having a first planar component comprising a plurality of rigid channel walls corresponding with a set of parallel channels; a resiliently deformable channel wall for each

channel, said resiliently deformable channel walls lying in a common plane; and a second planar component comprising a linear actuator for each channel, said actuators having respective actuation directions which are parallel; the resiliently deformable channel walls lying between and in a parallel relationship with the first and second planar components in the manufactured apparatus, with said actuation direction disposed orthogonal to said common plane and the actuators serving to actuate the respective channels through deformation of the associated resiliently deformable channel walls.

93. A method according to Claim 92, wherein the step of forming the first planar component comprises the step of forming a planar wafer and etching away material from one planar face of the wafer to define the channel walls.

94. A method according to Claim 93, wherein the step of forming the first planar component further comprises the step of etching away material from the other planar face of the wafer to define the resiliently deformable channel walls.

95. A method according to Claim 94, wherein the step of forming the first planar component comprises the step of depositing material after etching away material from said one planar face, the step of etching away material from the other planar face of the wafer serves define a layer of said deposited material as a resiliently deformable channel wall.

96. A method according to Claim 94 or Claim 95, wherein step of etching away material from the other planar face of the wafer to define the resiliently deformable channel walls serves to leave for each channel a push-rod connected with the associated resiliently deformable channel wall.

97. A method according to Claim 96, wherein each pushrod extends along substantially the length of the associated channel.

98. A method according to Claim 96 or Claim 97, wherein the step of forming the first planar component comprises the further step of forming an interaction layer bonded to the respective free ends of the pushrods.

99. A method according to any one of Claims 92 to 98, wherein said wafer is formed from silicon.

100. A method according to any one of Claims 93 to 99, wherein etching step comprises deep reactive ion etching.

101. A method according to Claim 95, wherein said wafer is formed from silicon and said deposited material comprises SiO_2 or SiN.

102. A method according to any one of Claims 92 to 101, wherein said second component is through the repeated formation and selective removal of layers.